Environmental factors influencing amphibian community assemblage in dune wetlands on the Lake Michigan coast

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Abstract

PURPOSE: Wetlands in dune landscapes provide important breeding habitat for amphibians along the Lake Michigan Coast. Unfortunately, these unique habitats and the corresponding amphibian metapopulations are understudied and threatened. The aim of this study is to determine what variables influence amphibian species richness and community composition in dune wetlands. SUBJECTS: We measured a number of variables at 16 permanent and ephemeral wetlands along the coast of Lake Michigan in Grand Haven, MI. METHODS AND MATERIALS: Species richness, wetland area, terrestrial habitat type, depth, hydroperiod, shade, and degree of isolation were measured from April to September of 2017. ANALYSES: Non-metric multidimensional scaling (NMDS), Least cost modeling (LCM), Principle components analysis (PCA), and Correlation testing were used. RESULTS: Nine species of amphibian were found in these wetlands; Green Frogs and Spring Peepers were most abundant, while Fowler's Toad was the rarest. LCM allowed us to determine the shortest navigable route between wetlands to determine wetland isolation, NMDS revealed that smaller wetlands in open dunes had different species assemblages than larger wetlands in forested habitat. PCA showed the correlations between hydroperiod, area, and depth; and correlation testing confirmed the strong positive relationship between species richness, area, and hydroperiod, and negative relationship between species richness and isolation. CONCLUSIONS: Species richness was higher in larger wetlands, with longer hydroperiods. However, some small temporary wetlands situated in the open dunes harbored rare species not found in other wetlands—highlighting the importance of protecting all of these habitats from land development, fragmentation and degradation.

Objectives

1. Assess amphibian species richness and environmental variables in a series of ephemeral and permanent dune wetlands with varying characteristics at Kitchel-Lindquist-Hartger Dunes Preserve and surrounding land in Grand Haven, Michigan.
2. Assess functional isolation of each wetland using least cost modeling (LCM) and terrestrial habitat type.
3. Correlate environmental data with species richness, observe trends and come to conclusion.

Methods

- Assessed amphibian species richness in 16 ephemeral and permanent dune wetlands (n=16) using multiple sampling methods: call monitoring, sight surveying (perimeter riparian and transect through wetland), D-netting, and egg mass sampling.
- Measured area (m^2) throughout the sampling period using Garmin GPSmap 62sc handheld GPS receiver.
- Monitor depth (cm) and hydroperiod (months) using water level monitors.
- Determine terrestrial habitat type of wetlands during sampling.
- Approximate percent shade from aerial photographs.
- Determine functional connectivity and isolation using least cost modeling within ArcGIS. Isolation scores are an average of the least cost route to the three closest wetlands from each site.
- Principal components analysis is used to explore patterns and observe correlations in abiotic data collected throughout the sampling period (April – September).
- Non-metric multidimensional scaling allows us visualize degree of similarity or dissimilarity in amphibian community composition between different wetlands and terrestrial habitat types.
- Spearman's rank-order correlation test assessed the relationship between wetland spatial area and species richness, as well as wetland hydroperiod and species richness.
- Welch's two sample t-test determined if there were significant differences in species richness between forested sites and great lake barrens / open dune sites.

Study Site

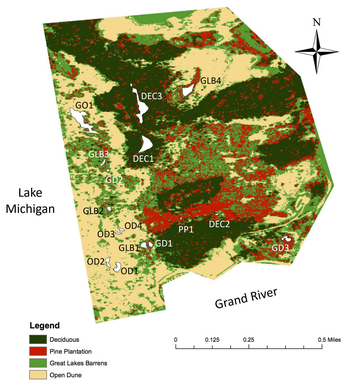
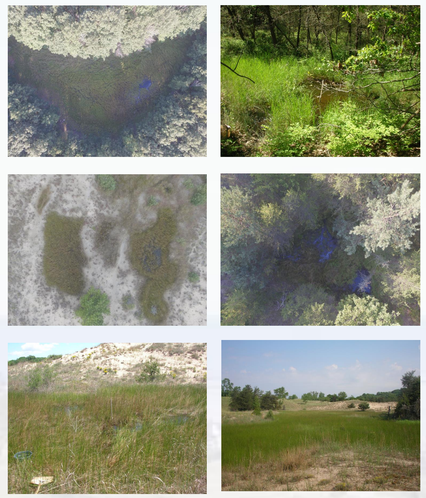


Fig 1. A map of wetland study sites and habitat types at Kitchel-Lindquist-Hartger Dunes Preserve, Grand Haven, MI.



Results

- Nine anuran species were found throughout the sampling period, and no salamanders were found.
- The most common species were Spring Peeper, Green frog, Gray Tree frog, and Wood frog. The rarest species found was the Fowler's toad (species of special concern in Michigan).
- Isolation scores ranged from 243 – 928.
    - Northern wetlands were, on average, much more connected to each other than southwestern wetlands.
- NMDS output and post-hoc ANOSIM showed significant clustering based on habitat type (p = 0.029).
    - Forested habitats, in addition to well connected sites and permanent sites had similar species assemblage. In contrast, open dune and great lake barrens habitats held different assemblages – typically lacking wood frog, and gray tree frog, but with a higher probability of finding American toad, and leopard frogs.
- PCA showed strong correlations between hydroperiod, area and depth; wetlands tended to get larger and deeper throughout the sampling period.
- A significant positive correlation existed between hydroperiod and species richness (r = 0.86, p < 0.001), as well as area and species richness (r = 0.6, p = 0.014).
- Isolation was significantly negatively correlated with species richness (r = - 0.29, p = 0.02)
- Although wetlands in forested habitat vs wetlands in dune/GL barrens habitats had different community assemblages, Welch's two sample t-test determined that there was no significant difference in species richness between the two (p = 0.618).

Table 1. Species found and frequency of occurrence during wetland sampling at Kitchel-Lindquist-Hartger Dunes Preserve from April-September 2017.

Species	# of wetlands present
Spring Peeper (*Pseudacris crucifer crucifer)*	14
Green Frog (*Rana clamitans melanota)*	13
Gray Tree Frog (*Hyla versicolor)*	11
Wood Frog (*Rana sylvatica)*	10
American Toad (*Bufo americanus americanus)*	7
Chorus Frog (*Pseudacris triseriata triseriata)*	3
Leopard Frog (*Rana pipiens)*	3
Bull Frog (*Rana catesbeiana)*	2
Fowlers Toad (*Bufo fowleri)*	1

Table 2. Abiotic variables and species richness in wetlands at Kitchel-Lindquist-Hartger Dunes Preserve during sampling from April-September 2017. Hydroperiod values reflect one year of observation April 2017 – April 2018. Isolation was rounded to the nearest whole number and is the average of the least cost distance from each wetland to its nearest three neighbors. Area was averaged throughout the sampling period and rounded to the nearest whole number.

Wetland	Terrestrial Habitat	Average Area (m^2)	Isolation score	Hydroperiod (months)	Shade %	Species Richness
OD1	Open Dune	910	895	9	0	5
OD2	Open Dune	467	928	6	0	2
OD3	Open Dune	143	648	3	0	3
OD4	Open Dune	197	581	6	0	3
GO1	GL Barrens/Open Dune	4259	642	12	5	7
GLB1	GL Barrens	439	291	8	10	4
GLB2	GL Barrens	134	880	3	70	2
GLB3	GL Barrens	96	446	3	40	2
GLB4	GL Barrens	2896	556	12	5	7
GD1	GL Barrens/Deciduous	266	243	8	70	4
GD2	GL Barrens/Deciduous	16	495	3	30	1
GD3	GL Barrens/Deciduous	123	572	3	20	4
DEC1	Deciduous	1161	442	12	5	4
DEC2	Deciduous	67	359	12	90	6
DEC3	Deciduous	2896	355	12	90	8
PP1	Pine Plantation	21	281	8	90	4

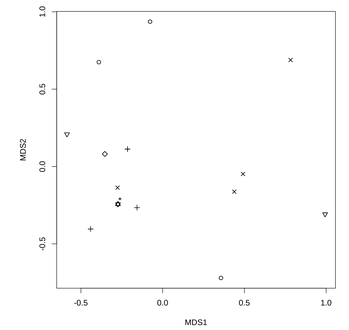


Fig 2. Non-metric multidimensional scaling of community assemblage in wetlands. Habitat type is delineated by symbol: X = open dune, O = great lake barrens, ◊ = great lake barrens/open dune, ∇ = great lake barrens/deciduous, + = deciduous, D = pine plantation. (*) denotes three sites with the same species assemblage: GLB1, GD1, PP1.

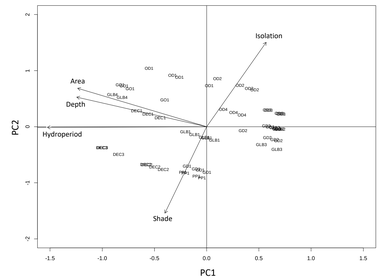


Fig 3. PCA of abiotic variables in relation to wetland sampling events. PC1 variance explained = 39.7%, PC2 variance explained = 31.9%. Points represent abiotic sampling events at wetlands, there is a general leftward trend of sites through time, indicating that throughout the sampling period, wetlands tended to get larger and increase in depth.

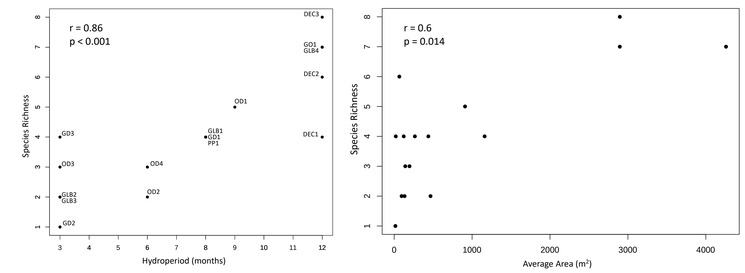


Fig 4. Significant positive correlation between species richness and wetland hydroperiod (months). Significant positive correlation between species richness and average wetland area (m^2).

Conclusions

- Species richness did not differ significantly between habitat types, however community assemblage did. This highlights the importance of protecting multiple types of wetlands due to the high degree of community variability between habitat types.
- Species richness was negatively correlated with isolation, indicating that greater isolation will result in lower species richness.
- Isolation analysis revealed that areas with more wetlands (small or large) increased overall connectivity of the entire ecosystem and should be valued as habitat for conservation concern, and as refugia for amphibians migrating to breeding pools.
- Species richness was significantly positively correlated with both hydroperiod and area, identifying larger and longer hydroperiod wetlands as a conservation priority.
- However, rare species such as Fowler's toad (a species of special concern) was only found in a shallow, short hydroperiod, isolated wetland. Highlighting the importance of all of these habitat types to overall amphibian biodiversity within the study site.

Acknowledgements

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